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Populations dynamic of *Pseudophacopteron* spp. (Hemiptera: Phacopteronidae), psyllids pest of *Dacryodes edulis* (Burseraceae) in Cameroon

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Abstract

Dacryodes edulis (G. Don) H. J. Lam (Burseraceae) is an oleiferous plant originated from Central Africa. This plant is cultivated for her fruits rich in proteins and lipids. The tree suffered serious damages caused by insect pests. In Cameroon, four psyllids species feed on *D. edulis*: *Pseudophacopteron tamessei*, *P. pusillum*, *P. eastopi* and *P. serrifer*. Larvae of *P. eastopi* produced fluorescent waxy filament which cover the young leaves of the buds. Larvae of *P. tamessei* induced the formation of galls on the upper surface of the leaves. The population dynamics of the four species was conducted in a natural secondary forest from May 2010 to April 2012. During this period, we collected adults, eggs and larvae of *P. tamessei, P. pusillum* and *P. eastopi.* Only adults of *P. serrifer* were collected. *Pseudophacopteron tamessei* was as the major psyllid pest of this plant. Four different generations of *P. tamessei* have been recorded each year, but during the second year, three generations of *P. eastopi* and *P. pusillum* were recorded. Two important generations were recorded in May and September. The number of generations varied from one psyllid species to another and from one year to another. Psyllids populations were correlated to the number of new buds and young shoots. The population dynamic of psyllids of *D. edulis* depends on the availability of new flushes on host plants. The integrated pest management will take into consideration the main flushing periods of the plant and the outbreak periods of psyllids in the Yaounde region.

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Introduction

Jumping plant-lice or psyllids form a moderate-size group of Hemiptera Sternorrhyncha. Their biology was review by Hodkinson (2009). Psyllids feed on plant-sap, usually from the phloem, and are generally highly host specific; psyllids are usually associated with dicotyledons, and related species often develop on related host taxa (Hodkinson, 1974). Higher psylloid taxa are typically associated with a single plant taxon, but contain a few members that develop on unrelated plant, suggesting an evolutionary process that includes both cospeciation and host shifts (Burckhardt, 1994). Hollis (2004) stated that the 3000 species are described in 235 recognized genus distributed universally, but with a larger diversity in the tropical regions and the temperate regions of the South. The known species are mainly those of the temperate and subtropical regions of the world. Several psyllids species of economically important agricultural crop plants and commercial timbers are under the permanent attack of the devastating indigenous psyllids pests. Therefore, psyllids are responsible for huge losses in orchards and plantations and also during regeneration of commercial timber species. In Cameroon, recent investigations enable us to study the biology of the main psyllids pests of cultivated plants and commercial timbers: *Mesohomotoma tessmanni* Aulmann, cocoa psyllid (Messi, 1987), *Trioza erytreae* Del Guercio, citrus psyllid (Tamesse and Messi, 2004), *Diclidophlebia eastopi* Vondraceck and *D. harrisoni* Osisanya, psyllid of *Triplochiton scleroxylon* (K. Schum) (Noubissi Youmbi *et al*, 2014). No investigation has been published on the biology of psyllids pests of *Dacryodes edulis* in Cameroon.

Dacryodes edulis (G. Don) H.J. Lam) (Burseraceae) is one of the most important arboricultural fruit in west and central Africa (Tchoundjeu *et al*., 2002). This plant is named by several names: african plum tree, african pear or bush butter tree, with reference to its richness in fatty acids and its exploitation which was then in the wild (Kengue, 2002). The fruit is commonly named Safou. Bush butter tree originated from the central Africa (Tchuenguem *et al.,* 2001). This plant grows naturally in the forest but it was gradually transferred in the agricultural landscape, where it is generally planted in association with cocoa and coffee trees (Schreckenberg *et al.,* 2002, Sonwa *et al*., 2002). In Cameroon, *D. edulis* is present throughout the southern part of the country and the Adamawa Region, for approximately 2/3 surface area of the country (Isseri, 1998). The exploitation and commercialization of Safou are important activities which improve the standard living of local population (Awono *et al*., 2002). The total exportation of safou from Cameroon was estimated to 93 995 t in 2007/2008; the increase of the exportation of this important fruits is gradually from one year to another (Anonymous, 2010). About 93 995 t of this fruit were exported mainly to USA, Europe, Gabon, Republic of Equatorial Guinea, Nigeria, (Anonymous, 2010). In Gabon, the local prize in the Libreville market according to Poligui *et al.* (2013) varied from 1.91 Euros to 4.07 Euros per kilogram. Indeed, Safou is mainly grown for its nutritional and commercial value (Tchoundjeu *et al.,* 2002). The export and local commercialization of Safou may improve the living conditions of local population in central Africa.

The principle value of the tree lies in its fruit. The leathery, shelled stone is surrounded by a pulpy, butryaceous pericarp about 5 mm thick, which is the portion eaten either raw or cooked in form of a sort of butter. It has a mild smell of turpentine and is oily. The fruits are boiled in saltwater, fried or roasted over charcoal. The fruit pulp yields about 48% edible oil, is rich in vitamins and contains a range of amino acids (Orwa *et al*., 2009). The essential oil obtained by hydrodistillation from the resin of *D. edulis* was simultaneously analyzed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) by Obame *et al.* (2008); twenty four components were identified in this essential oil. These authors examined the antioxidant capacity of the essential oil ; also, the essential oil was evaluated for its antimicrobial activity using disc diffusion and microdilution methods. The essential oil showed better activity against bacterial species than against yeast. These results seem to confirm that *D. edulis* is important in traditional medicine in Africa. Traditional healers in Nigeria and in the Democratic Republic of Congo use the plant to treat various infections. It is used in traditional medicine as a remedy for parasitic skin diseases, jigger, mouthwash, tonsillitis and drepanocytosis (Burkill, 1994; Mpiana *et al.*, 2007).

The african plum tree has suffered serious damages caused by insects pests, but the biology of theses insects pests are not yet been studied very well (kengue, 2002). A dipterous insect that mines the young leaves leads to continuous growth of the shoot because the leaflets drop before they mature; in Congo, a pyralid moth is the most important pest, leading to a burnt appearance of the leaves (Orwa *et al.,* 2009). In Cameroon, according to Kengue (2002), the larvae of a *Carpophilus* sp., a nitidulid beetle, eat the seed and when the adult bores its way out of the fruit secondary infections often lead to decay. Recent investigations in Cameroon indicated that four different psyllids species develop on this plant and causes important damages; the species involved are *Pseudophacopteron pusillum* Malenovský, Burckhardt, Tamesse , *P. serrifer* Malenovský & Burckhardt, *P. tamessei* Malenovský & Burckhardt and *P. eastopi* Malenovský, Burckhardt & Tamesse (Hemiptera: Phacopteronidae) (Malenovský *et al.*, 2007; Malenovský and Burckhardt, 2009). Psyllids or jumping plant lice are generally very host specific plant-sap sucking insects (Burckhardt *et al.*, 2006). Phacopteronidae family is pan-tropical in distribution and is associated with plants of the order Rutales/Sapindales (Anacardiaceae, Burseraceae, Meliaceae and Sapindaceae) and with Apocynaceae (Gentianales) (Hollis, 2004). Fifteen species of Phacopteronidae have been described from Afrotropical Region: one from Tanzania and Togo (Aulmann, 1912), three from South Africa (Capener, 1973), one from Yemen and Kenya (Burckhardt and Van Harten, 2006) and Nine from Cameroon (Malenovsky *et al*, 2007, Malenovsky and Burckhardt, 2009) and recently Tamesse *et al.* (2014) described one new species again from Cameroon. The growth and the development of the plant, *D. edulis*, are greatly reduced; larvae of *P. tamessei* induced the formation of galls on leaves and those of *P. eastopi* produced whitish flocculent waxy secretions. No control measures have been taken so far to fight against the new psyllids pests of *D. edulis* in Cameroon. The control of the insect pests is based on a thorough understanding of their population dynamics (Riba and Silvy, 1989). According to Milaire (1987), studies on population dynamics help to keep pest populations below the threshold of economic damage by insecticides. It allows finding strategies to optimize the use of chemicals in Integrated Program of control (Webb, 1977) and provides useful information for taking preventive measures against the resurgence of infestations (Nyeko *et al.*, 2002).

The aim of this work was to study the population dynamics of *Pseudophacopteron pusillum*, *P. serrifer*, *P. tamessei* and *P. eastopi* which feed on *D. edulis* in Cameroon. Abiotic and biotic factors that regulated natural populations of the pests are investigated.

Material and method

Site and period of study

The study was conducted for two consecutive years from May 2010 to April 2012 in an experimental orchard of the Institute of Agronomic Research for Development (IRAD), Nkolbisson, VIIth district of Yaounde. The altitude and geographical coordinates are: 740 m, 03 ° 52'290'' N 11 ° 25'420'' E.

Sampling method

Host plants were planted 15 years ago. The total number of plants regularly examined was 100. Thirty plants were chosen randomly for psyllids collection. These plants received no pesticide treatment before and during the study period. Sampling was done once a week from May 2010 to April 2012 (24 months). Adult psyllids were captured with a sweep net of 0.5 mm mesh size and an aspirator. From each of the 30 trees, five young buds were collected for eggs and larvae surveys in the laboratory. Also, five buds cover with whitish flocculent waxy secretions or young branches with leaves cover with galls produced by psyllids were collected. All specimens were preserved in 70% ethanol and kept in the laboratory and were examined under a stereomicroscope. In the laboratory, adults of each species were counted and grouped to male and female. Larval stages, early (L1, L2, L3) and advanced (L4, L5) larval stages of each species were identified and their number counted. Meteorological data were obtained from the Institute of Agricultural Research for Development (IRAD), Nkolbisson. The selected parameters are temperature, relative humidity, rainfall, wind speed and insolation.

Study of flushing rhythm of D. edulis

During each survey, the number of young buds and young branches were counted on each of the 30 trees. These buds and branches were counted randomly in a ¼ selected part of the tree.

Data analysis

SPSS statistical program was used to compare mean with nonparametric Wilcoxon and Mann-Whitney tests ($P<0.05$). This program was also used to calculate the Spearman correlations between abiotic and biotic factors regulation population dynamic of *Pseudophacopteron* spp, psyllids of *D. edulis*.

Results

Numerical variations of D. edulis psyllids

Four psyllids species were regularly collected on *Dacryodes edulis* at Nkolbisson during this study. The psyllids involved are *Pseudophacopteron pusillum*, *P. serrifer*, *P. tamessei* and *P. eastopi*. Adults for all the psyllid species were regularly collected on host plant. But eggs and larvae of *P. serrifer* were absent on host plant. Maybe this plant is not suitable for the development of eggs and larvae of *P. serrifer* in our region and the eggs laying sites of this psyllid could be different from *D. edulis*. Consequently, the study of the population dynamic was complete for the three others psyllid species, *Pseudophacopteron pusillum*, *P. tamessei* and *P. eastopi*.

Table 1. Number of psyllids counted on *Dacryodes edulis* during the two years of study and comparison of mean of the two consecutive years by non parametric Mann whitney statistic test ($P<0.05$).

psyllids species	*developmental stages*	*parameters*	*1rst year May 2010-April 2011*	*2nd year May 2011-April 2012*	*Mann-Whitney test : U*
P. tamessei	*adults*	*total*	550	339	0.009**
		mean	10.78	6.40	
	eggs	*total*	1509	1445	0.556NS
		mean	29.59	27.26	
	early larval stages	*total*	2030	915	0.722NS
		mean	39.80	17.26	
	advanced larval stages	*total*	388	192	0.238NS
		mean	550	339	0.009**
P. pusillum	*adults*	*total*	91	45	0.049*
		mean	1.78	0.85	
	eggs	*total*	103	46	0.092NS
		mean	2.02	0.87	
	early larval stages	*total*	109	34	0.031*
		mean	2.14	0.64	
	advanced larval stages	*total*	97	29	0.010*
		mean	91	45	0.049*
P. eastopi	*adults*	*total*	137	67	0.008**
		mean	2.69	1.26	
	eggs	*total*	327	191	0.404NS
		mean	6.41	3.60	
	early larval stages	*total*	323	442	0.974NS
		mean	6.33	8.34	
	advanced larval stages	*total*	244	110	0.004**
		mean	4.78	2.08	
P. serrifer	*adults*	*total*	330	281	0.105NS
		mean	6.47	5.30	

NS: not significant, *significant difference, **highly significant difference.

Numerical variations of P. tamessei population

The number of adults of *P. tamessei* counted on *D. edulis* was 889 adults with 453 males and 436 females. The sex ratio, in favour of males, was 1.04. The number of eggs recorded was 2954 eggs. The number of larvae of early stages was 2945 larvae and the number of larvae of advanced stages was 520 larvae (table 1).

Table 2. Spearman correlation between populations of *Pseudophacopteron tamessei* and some biotic and abiotic parameters of the study site from May 2010 to April 2012.

Parameters	*Developmental stages*			
	eggs	early larvae	advanced larvae	adults
Temperature				
R	0.116	0.48	-0.206	0.46
P<	0.24^{NS}	0.627^{NS}	0.037**	0.645^{NS}
Humidity				
R	-0.142	-0.050	0.120	-0.087
P<	0.154^{NS}	0.619^{NS}	0.229^{NS}	0.381^{NS}
Wind speed				
R	0.195	-0.129	0.13	0.055
P<	0.048*	0.193^{NS}	0.893^{NS}	0.581^{NS}
Insolation				
R	0.26	0.130	-0.143	0.001
P<	0.791^{NS}	0.190^{NS}	0.149^{NS}	0.988^{NS}
Rainfall				
R	-0.193	0.71	-0.106	0.007
P<	0.051*	0.477^{NS}	0.286^{NS}	0.948^{NS}
Buds				
R	0.493	0.224	-0.550	0.639
P<	0.000**	0.023**	0.000**	0.000**
Y. shoots				
R	0.406	0.372	-0.462	0.574
P<	0.000**	0.000**	0.000**	0.000**

R: spearman correlation coefficient, P: probability value, NS: not significant, *Significant correlation, **Highly significant correlation, *Y. shoots: Young shoots.*

Numerical variation of adults

The numerical variation of adults' population of *P. tamessei* showed during the first year (from May 2010 to April 2011) three main periods of psyllids outbreaks from May to August 2010 for the first period; from September to November 2010 for the second period and from December 2010 to April 2011 for the third period. Three main peaks were obtained respectively in September 2010, December 2010 and March 2011. The most important peak occurred in September 2010 (Fig. 1). The different peaks could express the number of generations of this psyllid during the first year of study. During the second year of study (from May 2011 to April 2012), three main periods were observed, from From May to August 2011 for the first period, from September to December 2011 for the second period and from January to April 2012 for the third period. We observed three peaks of adults of *P. tamessei* in September 2011, January and February 2012 (Fig.1). The number of generation is the same as the one recorded during the first year of study.

The statistical analysis showed that the number of adults of *P. tamessei* counted during the first year (550) was greater than the number counted during the second year (339). The comparison by the Mann Whitney non parametric test showed a highly significant difference, P = 0.009 (table 1).

Numerical variation of eggs

During the first year of study, no egg was counted from May to August 2010, three peaks of egg – laying were obtained during the months of September 2010, December 2010 and March 2011 (Fig. 2). During the second year, we noticed four peaks of egg-laying in June 2011, September 2011, January 2012 and March 2012 (Fig. 2).

Table 3. Spearman correlation between populations of *Pseudophacopteron pusillum* and some biotic and abiotic parameters of the study site from May 2010 to April 2012.

Parameters	*Developmental stages*			
	eggs	early larvae	advanced larvae	adults
Temperature				
R	0.118	0.94	0.124	0.033
P<	0.237^NS	0.342^NS	0.214^NS	0.742^NS
Humidity				
R	-0.100	-0.087	-0.079	0.029
P<	0.315^NS	0.380^NS	0.430^NS	0.769^NS
Wind speed				
R	0.156	0.139	0.006	-0.086
P<	0.115^NS	0.161^NS	0.952^NS	0.385^NS
Insolation				
R	0.166	0.136	0.140	0.030
P<	0.094^NS	0.169^NS	0.159^NS	0.764^NS
Rainfall				
R	0.205	0.124	0.151	0.123
P<	0.038*	0.211^NS	0.128^NS	0.215^NS
Buds				
R	0.443	0.502	0.437	0.412
P<	0.000**	0.000**	0.000**	0.000**
Y.shoots				
R	0.402	0.447	0.457	0.469
P<	0.000**	0.000**	0.000**	0.000**

R: spearman correlation coefficient, P: probability value, NS: not significant, **Significant correlation, **Highly significant correlation,* Y. shoots: Young shoots.

The statistical analysis showed that the number of eggs of *P. tamessei* counted during the first year (1509) was higher than the number of eggs counted during the second year (1445), but the Mann Whitney non parametric test showed no significant difference (P>0.05) (table 1).

Numerical variation of larvae

During the first year, the larvae of early stages of *P. tamessei* showed four peaks respectively in June 2010, October 2010, January 2011 and April 2011. During the second year, the larvae of early stages showed four peaks, grouped in three periods. The first period extended from May to July 2011, the second from August to December 2011 and the last from January to April 2012. The important peaks were recorded at July, November 2011 and April 2012 (Fig. 3). The numerical variation of advanced larval stages of *P. tamessei* showed during the first year three main peaks in July, November 2010 and February 2011. During the second year, we observed equally three main peaks in May, August, and December 2011 (Fig. 4).

The statistical analysis showed that the number of larvae of early and advanced stages of *P. tamessei* recorded during the first year (2030 for earlier larval stages and 388 for advances larval stages) was higher than the number counted during the second year (915 for earlier larval stages and 192 for advances larval stages); but the Mann Whitney non parametric test showed no significant difference (P>0.05) (table 1).

Numerical variation of P. pusillum population

The number of adults of *P. pusillum* counted on *D. edulis* was 136 adults with 66 males and 70 females. The sex ratio, in favour of females, was 0.94. The number of eggs recorded was 149 eggs. The number of larvae of early stages was 143 larvae and the number of larvae of advanced stages was 126 larvae (table 1).

Table 4. Spearman correlation between populations of *Pseudophacopteron eastopi* and some biotic and abiotic parameters of the study site from May 2010 to April 2012.

Parameters	Developmental stages			
	eggs	early larvae	advanced larvae	adults
Temperature				
R	0.102	-0.034	-0.148	-0.022
P<	0.304^{NS}	0.737^{NS}	0.136^{NS}	0.826^{NS}
Humidity				
R	-0.48	0.075	0.101	0.145
P<	0.627^{NS}	0.452^{NS}	0.312^{NS}	0.143^{NS}
Wind speed				
R	-0.152	-0.166	-0.217	-0.130
P<	0.124^{NS}	0.093^{NS}	0.028**	0.192^{NS}
Insolation				
R	0.94	-0.012	-0.008	0.017
P<	0.344^{NS}	0.907^{NS}	0.933^{NS}	0.866^{NS}
Rainfall				
R	0.113	0.184	0.118	0.244
P<	0.256^{NS}	0.063^{NS}	0.234^{NS}	0.013***
Buds				
R	0.419	0.480	0.572	0.525
P<	0.000**	0.000**	0.000**	0.000**
Y. shoots				
R	0.360	0.423	0.520	0.591
P<	0.000**	0.000**	0.000**	0.000**

R: spearman correlation coefficient, P: probability value, NS: not significant, *Significant correlation, **Highly significant correlation, *Y. shoots: Young shoots.*

Numerical variation of adults

The numerical variation of adults' population of *P. pusillum* showed during the first year (from May 2010 to April 2011) three main periods of psyllids outbreaks from May to September 2010 for the first period; from October 2010 to January 2011 for the second period and from February to April 2011 for the third period. Five main peaks were obtained respectively in July, November, December 2010, February and April 2011. The most important peak occurred in June 2010 and April 2011 (Fig. 5). The different peaks could express the number of generations of this psyllid during the first year of study. During the second year of study (from May 2011 to April 2012), three main periods were observed, from From May to August 2011 for the first period, from September to December 2011 for the second period and from January to April 2012 for the third period. We observed three peaks of adults of *P. pusillum* in June, October 2011, and January 2012 (Fig. 5). The number of generation is different from the one recorded during the first year of study.

The statistical analysis showed that the number of adults of *P. pusillum* counted during the first year (91) was greater than that counted during the second year (45). The comparison by the Mann Whitney non parametric test showed however a significant difference, P = 0.049 (table 1).

Numerical variation of eggs

During the first year of study, no egg was counted from May to August 2010, four peaks of egg – laying were obtained during the months of September, November 2010 and February, April 2011 (Fig. 6). During the second year, we noted three peaks of egg-laying in June, October 2011and January 2012 (Fig. 6).

The statistical analysis showed that the number of eggs of *P. pusillum* counted during the first year (103) was higher than the number of eggs counted during the second year (46), but the Mann Whitney non parametric test showed no significant difference (P>0.05) (table 1).

Table 5. Spearman correlation between populations of *Pseudophacopteron serrifer* and some biotic and abiotic parameters of the study site from May 2010 to April 2012.

Parameters	*P. serrifer* adults	Buds	Young shoots
Temperature			
R	0.029	-0.068	-0.029
P<	0.768^{NS}	0.494^{NS}	0.768^{NS}
Humidity			
R	0.025	0.168	0.213
P<	0.803^{NS}	0.090^{NS}	0.031*
Wind speed			
R	0.040	-0.095	-0.037
P<	0.685^{NS}	0.338^{NS}	0.713^{NS}
Insolation			
R	-0.117	-0.053	-0.024
P<	0.238^{NS}	0.595^{NS}	0.809^{NS}
Rainfall			
R	-0.027	0.237	0.265
P<	0.790^{NS}	0.016**	0.007**
Buds			
R	0.553	1.000	0.870
P<	0.000**		0.000**
Young shoots			
R	0.451	0.870	1.000
P<	0.000**	0.000**	

R: spearman correlation coefficient, P: probability value, NS: not significant, *Significant correlation, **Highly significant correlation.

Numerical variation of larvae

During the first year, the larvae of early stages of *P. pusillum* showed five peaks respectively in September, December, November 2010, February and April 2011. During the second year, the larvae of early stages showed three peaks in June, October 2011 and January 2012 (Fig. 7). The numerical variation of advanced larval stages of *P. pusillum* showed during the first year five main peaks in September, November, December 2010, February and April 2011. (Fig.8). During the second year of study, three peaks of larval of earlier and advanced stages were obtained respectively in June, October 2011 and January 2012. The statistical analysis showed that the number of larvae of early and advanced stages of *P. pusillum* recorded during the first year (109 for earlier larval stages and 97 for advances larval stages) was higher than the number counted during the second year (34 for earlier larval stages and 29 for advances larval stages); the Mann Whitney non parametric test showed a significant difference for early larval stages (P=0.031) and advanced larval stages (P=0.010) (table 1).

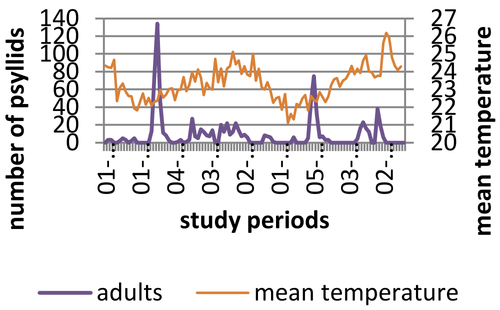

Fig. 1. Numerical variation of adults of *Pseudophacopteron tamessei* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variations of P. eastopi population

The number of adults of *P. eastopi* counted on *D. edulis* was 210 adults with 100 males and 110 females. The sex ratio, in favour of females, was 0.91. The number of eggs recorded was 518 eggs. The number of larvae of early stages was 774 larvae and the number of larvae of advanced stages was 354 larvae (table 1).

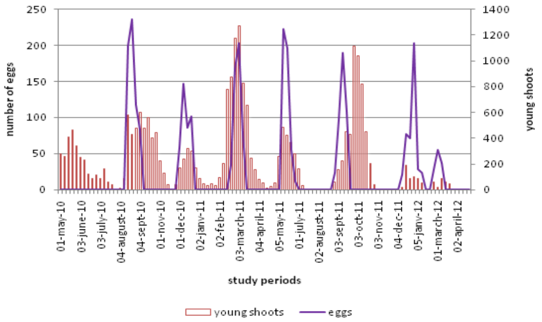

Fig. 2. Numerical variation of eggs of *Pseudophacopteron tamessei* depending on the flushing rhythm variation of the host plants in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variation of adults

The numerical variation of adults' population of *P. eastopi* showed during the first year (from May 2010 to April 2011) three main periods of psyllids outbreaks from May to August 2010 for the first period; from September 2010 to January 2011 for the second period and from February to April 2011 for the third period. Five main peaks were obtained respectively in July, September, November 2010, January and March 2011. The two important peaks occurred in July 2010 and March 2011 (Fig. 9). The different peaks could express the number of generations of this psyllid during the first year of study. During the second year of study (from May 2011 to April 2012), three main periods were observed, from From May to August 2011 for the first period, from September to December 2011 for the second period and from January to April 2012 for the third period. We observed three peaks of adults of *P. eastopi* in June, September 2011, and February 2012 (Fig.9). The number of generation is five during the first year of study and three during the second year of study.

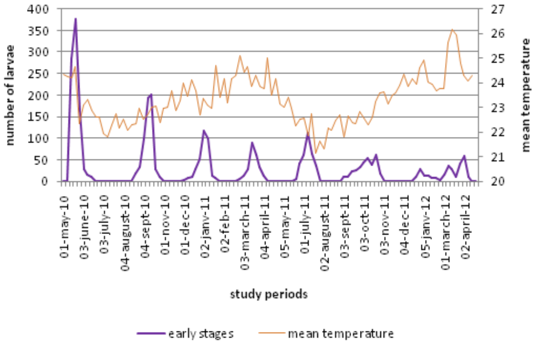

Fig. 3. Numerical variation of larvae of early stages (larvae of 1st, 2nd and 3rd stages) of *Pseudophacopteron tamessei* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

The statistical analysis showed that the number of adults of *P. eastopi* counted during the first year (137) was greater than that counted during the second year (67). The comparison by the Mann Whitney non parametric test showed however a highly significant difference, P = 0.008 (table 1).

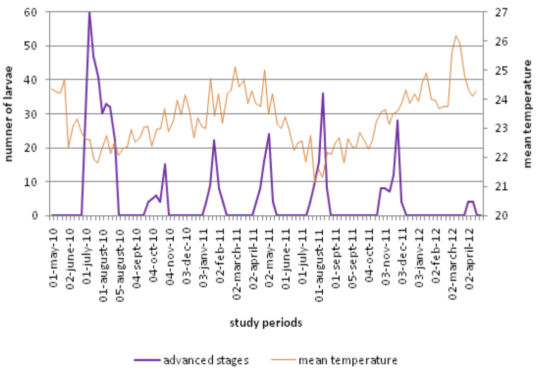

Fig. 4. Numerical variation of larvae of advanced stages (4th and 5th stages) of *Pseudophacopteron tamessei* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variation of eggs

During the first year of study, no egg was counted from May to August 2010, four peaks of egg – laying were obtained during the months of September, December 2010 and February, April 2011 (Fig. 10). During the second year, we noted three peaks of egg-laying in May, September 2011 and January 2012 (Fig. 10).

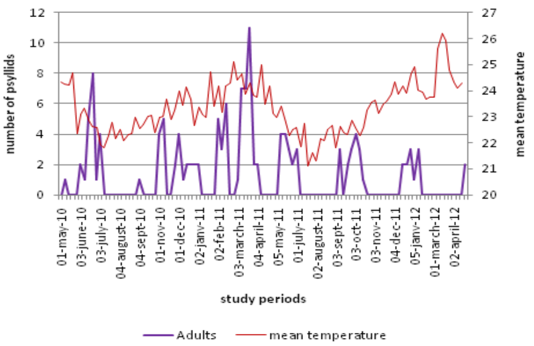

Fig. 5. Numerical variation of adults of *Pseudophacopteron pussilum* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

The statistical analysis showed that the number of eggs of *P. eastopi* counted during the first year (137) was higher than the number of eggs counted during the second year (67), but the Mann Whitney non parametric test showed no significant difference (P>0.05) (table 1).

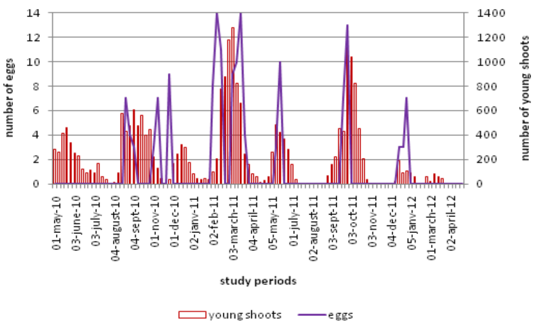

Fig. 6. Numerical variation of eggs of *Pseudophacopteron pussilum* depending on the flushing rhythm variation of the host plants in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variation of larvae

During the first year, the larvae of early stages of *P. eastopi* showed five peaks respectively in September, November, December 2010, February and April 2011. During the second year, the larvae of early stages showed three peaks in May, September 2011 and February 2012 (Fig. 11). The numerical variation of advanced larval stages of *P. eastopi* showed during the first year six main peaks in July, September, November 2010, January, February and April 2011 (Fig. 12). During the second year, two peaks were obtained respectively in May, September and October 2011 (Fig. 12).

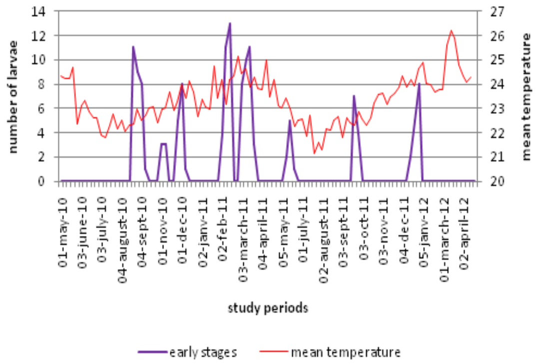

Fig. 7. Numerical variation of larvae of early stages (larvae of 1st, 2nd and 3rd stages) of *Pseudophacopteron pussilum* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

The statistical analysis showed that the number of larvae of early and advanced stages of *P. eastopi* recorded during the second year (442 for earlier larval stages and 110 for advances larval stages) was higher than the number counted during the first year (323 for earlier larval stages and 244 for advances larval stages); the Mann Whitney non parametric test showed a highly significant difference for advanced larval stages (P=0.004) (table 1).

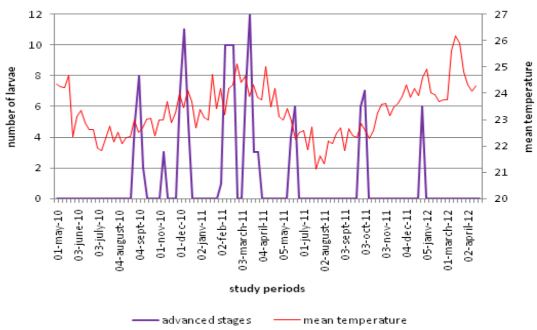

Fig. 8. Numerical variation of larvae of advanced stages (4th and 5th stages) of *Pseudophacopteron pussilum* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variation of adults of P. serrifer

The number of adults of *P. serrifer* counted on *D. edulis* was 611 adults with 359 males and 252 females. The sex ratio, largely in favour of males, was 1.42. No egg and larvae was collected on host plant during this study (table 1).

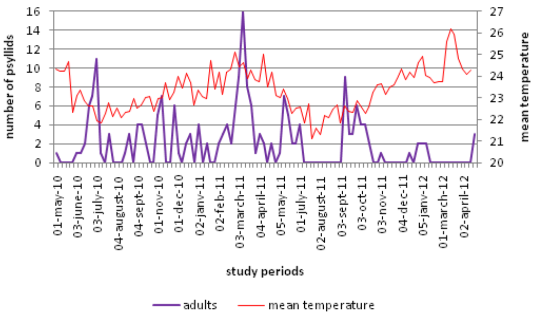

Fig. 9. Numerical variation of adults of *Pseudophacopteron eastopi* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Numerical variation of adults

The numerical variation of adults' population of *P. serrifer* showed during the first year (from May 2010 to April 2011) three main periods of psyllids outbreaks from May to November 2010 for the first period; from December 2010 to February 2011 for the second period and from March to April 2011 for the third period. Four main peaks were obtained respectively in June, September, December 2010 and March 2011. The two important peaks occurred in September 2010 and December 2010 (Fig. 13). The different peaks could express the number of generations of this psyllid during the first year of study. During the second year of study (from May 2011 to April 2012), two main periods were observed, from May to December 2011 for the first period, from January to April 2012 for the second period. We observed three peaks of adults of *P. serrifer* in June, September 2011, and January 2012 (Fig.13). The number of generation is four during the first year of study and three during the second year of study.

The statistical analysis showed that the number of adults of *P. serrifer* counted during the first year (330) was greater than that counted during the second year (281). But the comparison by the Mann Whitney non parametric test showed a non significant difference, P>0.05. (table 1).

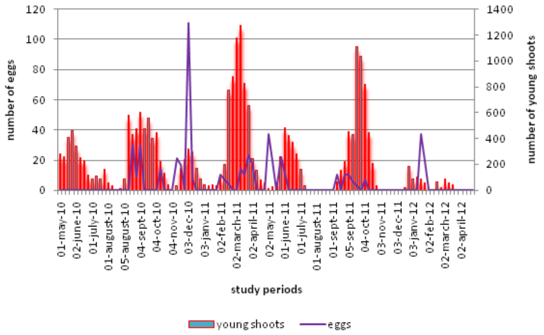

Fig. 10. Numerical variation of eggs of *Pseudophacopteron eastopi* depending on the flushing rhythm variation of the host plants in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Considering the total number of each psyllid species of *D. edulis* psyllids, Fig. 14 matched the numerical variation of each species. *P. tamessei* seems to be considered as the major pest of this plant, four different generations of this psyllid have been recorded each year and two important generations were recorded in May and September 2010. For *P. eastopi* and *P. pusillum*, four generations have been recorded during the first year of study and three generations during the second year of study. The number of generations varied from one year to another and from one species to another.

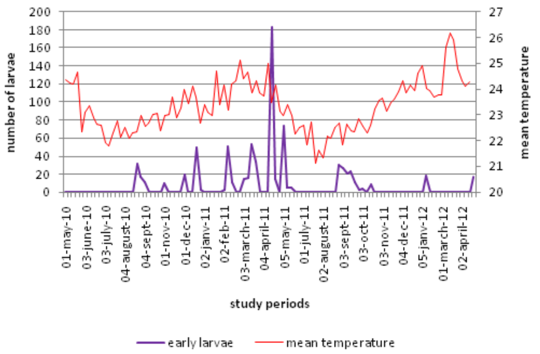

Fig. 11. Numerical variation of larvae of early stages (larvae of 1st, 2nd and 3rd stages) of *Pseudophacopteron eastopi* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Impact of biotic and abiotic factors on the numerical variation of D. edulis Psyllids

The ombrothermic diagram of Yaounde (Fig. 15) shows four seasons with two rainy seasons and two dry seasons: rainy season, August – November and March –July; dry season, November – March and July - August.

Effects of abiotic factors on the numerical variations of D. edulis psyllids populations

The Spearman correlations between the numerical variation of individuals of *Pseudophacopteron tamessei* and temperature is significant for advanced larval stages, R=-0.206; P=0,037 (tables 2). Then when the temperature is higher, the number of psyllids of advanced larval stage of *P. tamessei* decreased. No significant Spearman correlation was recorded between temperature and psyllids counted on *D. edulis* (P>0.05) (tables 2-5). These results are in contrast with the impact of temperature on the population dynamic of *Trioza erytreae* Del Guercio, citrus psyllid in Cameroon (Tamesse and Messi, 2004). According to Tamesse and Messi (2004) temperature is negatively correlated to citrus psyllid population in Yaounde so that when the level of the temperature increased, the number of psyllids decreased. Also, according to Noubissi Youmbi *et al.* (2014), the numerical variation of larval and adults stages of *Diclidophlebia eastopi* Vondracek and *Diclidophlebia harrisoni* Osisanya, psyllid of *Triplochiton scleroxylon* (K. Schum) depends on the variation of temperature. In this case, temperature is positively correlated to the psyllid population.

The Spearman correlations between the numerical variation of psyllids populations and relative humidity are positive but non significant for all stages of development and *Pseudophacopteron* spp. (P>0.05) (tables 2 - 5). Maybe the relative humidity has no impact on the numerical variation of psyllids of *D. edulis*. This result is in contrast to the findings of Noubissi Youmbi *et al* (2014) who concluded that when the average level of relative humidity is higher, the number of *D. eastopi* and *D. harrisoni* could be low on host plant.

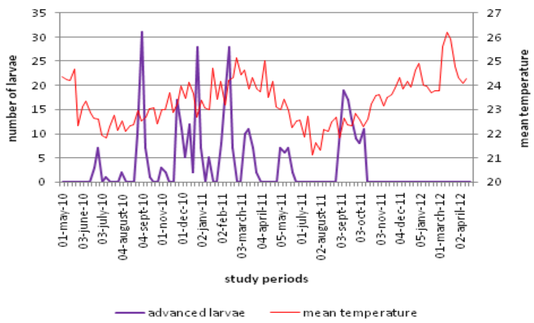

Fig. 12. Numerical variation of larvae of advanced stages (4th and 5th stages) of *Pseudophacopteron eastopi* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

The Spearman correlation between wind speed and the numerical variation of psyllids are significant for the eggs (R=0.195, P=0.048) and advanced larval stages of *P. tamessei* (R=-0.217, P=0.028) (table 2). Indeed the positive correlation between the wind speed and the numerical variation of eggs indicated that when the wind speed is higher, the number of eggs laid could be also high. According to the same result, the number of larvae counted could be very low when the level of wind speed is higher. No others significant correlation was recorded between psyllids population and wind speed during this study (P>0.05) (tables 2-5).

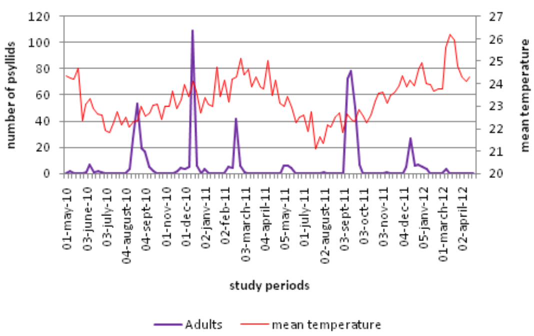

Fig. 13. Numerical variation of adults of *Pseudophacopteron serifer* depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

The Spearman correlations between the numerical variation of psyllids populations and insolation are non significant for all developmental stages of

Pseudophacopteron spp. (P>0.05) (tables 2-5). Maybe insolation has no impact on the numerical variation of psyllids of *D. edulis*. This result is in contrast to the findings of Noubissi Youmbi *et al.* (2014) who noted a higher significant correlation between the level of insolation and the number of *D. eastopi* and *D. harrisoni* in Yaounde.

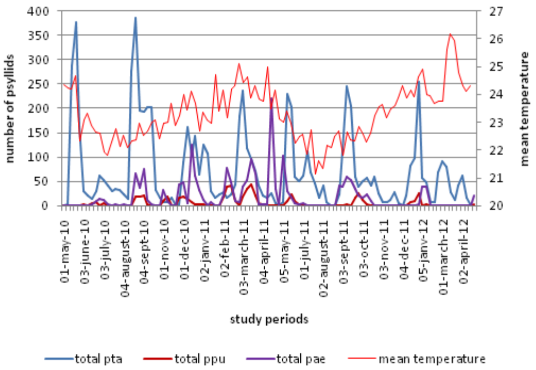

Fig. 14. Numerical variation of *Pseudophacopteron* spp. depending on the temperature variation in an experimental *D. edulis* plantation in Nkolbisson (Yaounde) from May 2010 to April 2012.

Impact of the flushing rhythm of D. edulis

During the first year of study from May 2010 to April 2011, we observed four main periods of flushing rhythm of *D. edulis*; the peaks were recorded respectively in June, September, December 2010 and March 2011. The most important peak was in March 2011. All over the year, host plants usually have young shoots available for eggs laying site of psyllids. From May 2011 to April 2012, we observed three main periods of flushing rhythm respectively from May to July 2011, from September to November 2011 and lastly from January to March 2012. The peaks were recorded respectively in June, October 2011 and January 2012. The peak of October 2011 was the must important peak. During this year, the flushing period were separated by resting period during which no young shoots was available for psyllid feeding or eggs laying sites. The Spearman correlation between rain fall and the number of new flushes is as follow: buds, R=0.237; P=0.016; young shoots, R=0.265; P=0.007. The production of new flushes on *D. edulis* depends on the quantity of rain fall in our region. The Spearman correlations between the numerical variation of individuals of *Pseudophacopteron* spp and young shoots is highly significant for adults, eggs, larvae of *P. tamessei, P. pusillum*, *P. eastopi* and adults of *P. serrifer* (P< 0,0001) (table 5). Then, the numerical variation of psyllids of *D. edulis* depends on the availability of new flushes on host plant. New flushes are important eggs lying and feeding sites of psyllids.

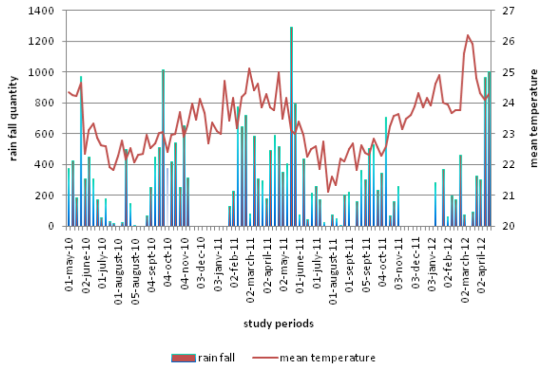

Fig. 15. Rainfall and mean temperature of the study region from May 2010 to April 2012 (source: Weather Station of study site).

Damages

Although the four species lives together in the same host plant, they cause different damages to their host plants. Larvae of *P. eastopi* produced fluorescent waxy filament which cover the young leaves of the buds (Fig. 16). Larvae of *P. tamessei* induced the formation of galls on the upper surface of the leaves. The leaves of *D. edulis* thus attacked become wrapped deformed, discoloured and fall down prematurely (Fig. 17). Damages slowed down the growth of the young's plants of *D. edulis*. All the four species deducted sap and reduce it for their host plant growth.

Discussion

During this survey in Nkolbisson (Yaounde - Cameroon), four psyllids species were regularly collected on *Dacryodes edulis* at Nkolbisson. The psyllids species involved are *Pseudophacopteron pusillum*, *P. serrifer*, *P. tamessei* and *P. eastopi*. In the same region, Noubissi Youmbi *et al.* (2014) collected two psyllids species of *Diclidophlebia* spp on *Triplochiton scleroxylon* but only psyllid species, *Trioza erytreae,* was collected on Citrus spp. (Tamesse and Messi, 2004) and *Mesohomotoma tessmanni* was also collected on *Theobroma cacao* L. (Messi *et al*., 1998). The number of psyllids species collected on *D. edulis* is quite different from later records on various host plants in Cameroon. This plant seems to be suitable for the development of *Pseudophacopteron pusillum*, *P. tamessei* and *P. eastopi*. Only adults of *P. serrifer* were collected during this study.

Fig. 16. Larvae of *P. eastopi* produced fluorescent waxy filament which cover young leaves of the buds of *Dacryodes edulis*.

The study of the numerical variation of psyllids of *D. edulis* revealed that psyllids outbreaks varied from one species to another and from one year to another. The population of *P. tamessei* seems to be considered as the major pest of this plant, four different generations of this psyllid have been recorded each year and two important generations occurred in May and September 2010. Four generations of *P. eastopi* and *P. pusillum* have been recorded during the first year of study and three generations during the second year of study. The number of generations recorded here is different from the records of other psyllids species in Yaoundé region. According to Noubissi Youmbi *et al*. (2014), *Diclidophlebia eastopi* and *D. harrisoni* feed on the same plant and the number of the generations for *Diclidophlebia eastopi* was 6 in 2009 and 2010 and five and seven respectively in 2009 and 2010 for *D. harrisoni*. The number of generations of *Trioza erytreae*, citrus psyllid varied also from one year to another from 7 to 3 generations in Yaounde (Tamesse and Messi, 2004).

Dacryodes edulis renews its leaves during four important periods. The important period occurred on March 2011 and October 2012 respectively during the small raining season and the higher raining season. The lowest production of new leaves was recorded during the dry season from July to August and from November to March. Rainfall seems to be important for the flushing rhythm of this plant. The correlation between the average number of young shoots and the total quantity of rainfall is positive and highly significant. The flushing rhythm of *D. edulis* is the same as the one recorded on *Citrus* spp. in the same locality (Tamesse and Messi, 2004). The correlation between the number of young shoots and psyllids population of each *Pseudophacopteron* species was positive and highly significant. These results showed the importance of the availability of new leaves for psyllids eggs laying sites and for the development of larvae and adults psyllids. These results confirmed the findings of various authors studying the interactions between psyllids and their host plants (Mensah and Madden, 1991; Van den berg *et al*., 1991; Geiger and Gutierrez, 2000; Tamesse and Messi, 2004; Noubissi Youmbi *et al*., 2014). Resource quality or abundance influence many aspects of insect consumer behavior and physiology, including food selection or feeding (Daugherty *et al*., 2007). The psyllids population feed on *D. edulis* pullulates when the trees produced buds and young shoots. This can be explained by the significant correlations obtained between the young shoots and the number of psyllids population recorded. Females lay eggs on buds and on young shoots. The vegetative status of the host plant hence plays a favourable role on the increase in the fecundity of the females and on the development of the psyllids larvae as stated by Nguyen (1972). Also, females exhibited a significantly greater preference for soft terminal shoots as these permit easier penetration of ovipositor and full insertion of the egg pedicel ensuring the uptake of water essential to egg viability (Mensah and Madden, 1991). In the same light, Tamesse and Messi (2004), who worked on the African citrus psyllids, noted strong correlations between the number of psyllids and the number of buds and young shoots of citrus; these organs are the preferential laying sites of *T. erytreae* females and they provided suitable conditions for adults and larvae breeding. Females of *P. pusillum*, *P. tamessei* and *P. eastopi* laid their eggs on buds of *D. edulis*. After hatching, the larvae of *P. eastopi* produced fluorescent waxy filament which cover the young leaves of the buds. Larvae of *P. tamessei* induced the formation of galls on the upper surface of the leaves. The leaves thus attacked become wrapped deformed and discoloured. The damages produced by *P. tamessei* could be compared to the damages done by psyllids of Triozidae family on their host plants as described by Tamesse *et al.*, (2007). The leaves dropped prematurely. However, despite the psyllids outbreaks, severe damages never results in the death of our experimental plants. These observations are consistent with the results of Noubissi Youmbi *et al.* (2014), Osisanya (1974) who studied the population dynamic of *Diclidophlebia* spp and damages caused by the pest on *T. scleroxylon*.

Fig. 17. Larvae of *P. tamessei* induced the formation of galls on the upper surface of the leaves of *Dacryodes edulis*.

The Spearman correlation between the numerical variation of individuals of *Pseudophacopteron tamessei* and temperature is significant for advanced larval stages of. These correlations between the numerical variation of psyllids populations and relative humidity and insolation were non significant for all stages of development and *Pseudophacopteron* spp. The Spearman correlation between wind speed and the numerical variation of psyllids are significant for the eggs and advanced larval stages of *P. tamessei*. Temperature seems to be important for the survival of psyllids larvae in our conditions. This result confirmed the findings of Tamesse and Messi (2004). Indeed, these climatic factors promote good growth of the host plants *D. edulis*. The abundance of carbohydrates in the leaves would promote adult activity that proliferates. The host plant phenology could be the main factor influencing the population dynamic of the four psyllids of *D. edulis*. The integrated pest management will take into consideration the main flushing periods of the plant and the outbreak periods of two psyllids in the Yaounde region. A good knowledge of the biology of *Pseudophacopteron* spp. is important to ensure the effectiveness of chemical control and protection of seedlings and saplings. Similarly, the search for natural enemies of the psyllid is a major challenge for the limitation of natural populations of these pests.

Conclusion

Four psyllids species, *Pseudophacopteron* spp., feed on *D. edulis* in Cameroon. The number of adults of *P. tamessei* counted on *D. edulis* was 889 (453 males and 436 females). The number of eggs recorded was 2954 eggs. The number of larvae of early and advanced stages was respectively 2945 and 520 larvae. The number of adults of *P. eastopi* counted on *D. edulis* was 210 adults (100 males and 110 females). The number of eggs recorded was 518 eggs. The number of larvae of early and advanced stages was respectively 774 and 354 larvae. The number of adults of *P. pusillum* counted on *D. edulis* was 136 adults (66 males and 70 females). The number of eggs recorded was 149 eggs. The number of larvae of early and advanced stages was respectively 143 and 126 larvae. The number of adults of *P. serrifer* counted on *D. edulis* was 611 adults (359 males and 252 females). No eggs and larvae of *P. serrifer* was collected on host plant during this study. *Pseudophacopteron tamessei* was as the major psyllid pest of this plant, four different generations of this psyllid species have been recorded each year and two important generations were recorded in May and September 2010. Four generations of *P. eastopi* and *P. pusillum* have been recorded during the first year and three generations during the second year. Only adults of *P. serrifer* were collected. The number of generations varied from one year to another and from one species to another. Psyllids populations were correlated to the number of new buds and young shoots. The population dynamic of psyllids of *D. edulis* depends on the availability of new flushes on host plants. The integrated pest management will take into consideration the main flushing periods of the plant and the outbreak periods of psyllids in the Yaounde region. Also, it will be important to identify natural enemies for biological control against psyllids pest of *D. edulis*.

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